

A GENERALIZED INVESTIGATION OF POTENTIALLY
POOR SOIL SUPPORT BY REGIONAL GEOMORPHIC
UNITS WITHIN THE ADJACENT 48 STATES

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BY

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JOINT HIGHWAY RESEARCH PROJECT
PURDUE UNIVERSITY AND
INDIANA STATE HIGHWAY COMMISSION



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TO: J. F. McLaughlin, Director February 2, 1971
Joint Highway Research Project

FROM: H. L. Michael, Associate Director
Joint Highway Research Project File No: 9-10-2

Attached is a technical paper entitled "A Generalized Investigation of Potentially Poor Soil Support by Regional Geomorphic Units Within the Adjacent 48 States". The paper was prepared for presentation at the 50th Annual Meeting of the Highway Research Board. It resulted from research performed under a National Cooperative Highway Research Program (NCHRP) contract.

The paper has been authored by M. W. Witczak, formerly on the JHRP staff and now with the Asphalt Institute, C. W. Lovell, and E. J. Yoder. The paper is presented to the Board for their information.

Respectfully submitted.

Harold L. Michael

Harold L. Michael
Associate Director

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A GENERALIZED INVESTIGATION OF POTENTIALLY
POOR SOIL SUPPORT BY
REGIONAL GEOMORPHIC UNITS WITHIN THE ADJACENT 48 STATES

by

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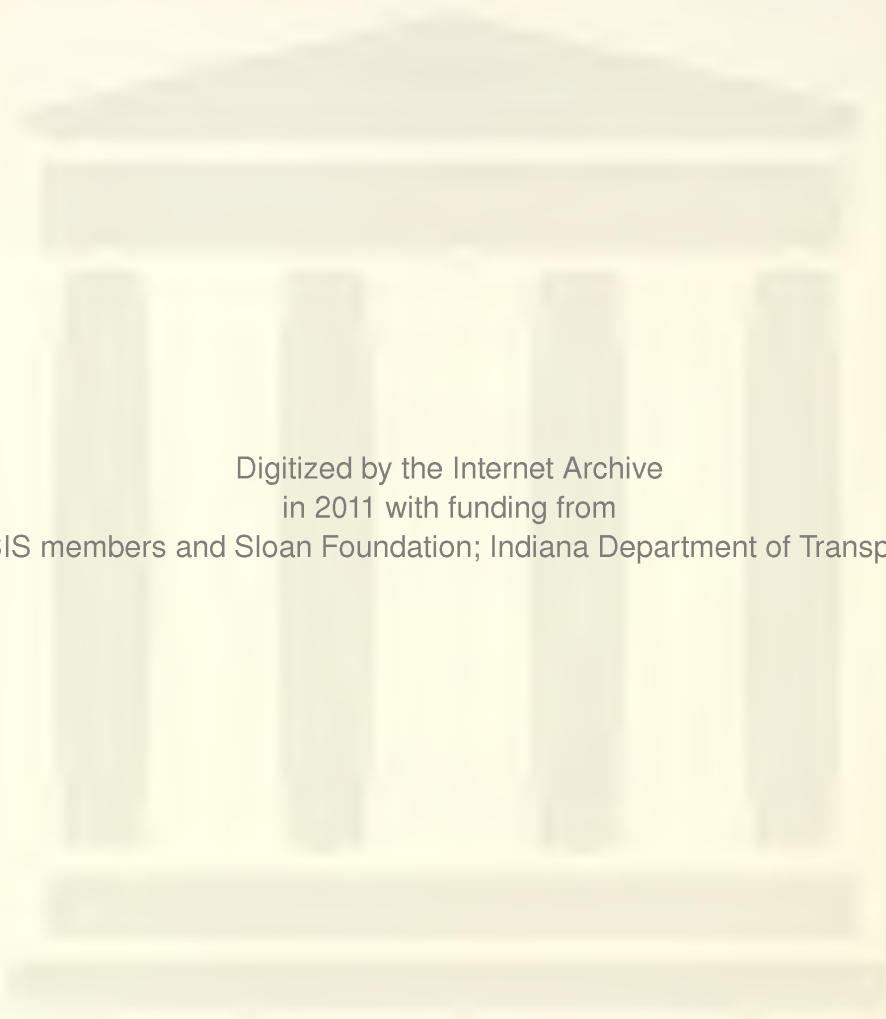
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A paper submitted to the Highway Research Board
for presentation at the 50th Annual Meeting, Washington, D. C., January 1971

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INFORMATIVE ABSTRACT

A Generalized Investigation of Potentially Poor Soil Support by Regional Geomorphic Units Within the Adjacent 48 States

by

Matthew W. Witczak, C. W. Lovell, Jr. and E. J. Yoder

This report qualitatively assesses the potential for poor soil support within the adjacent 48 states. For each of 97 physiographic sections, an estimate was made of: (a) the frequency of occurrence of organic deposits, and (b) the combined frequency of occurrence-severity rating of clayey deposits.

In order to assess the regional character of the poor support problem, a national soil textural map was developed. Frequency of occurrence ratings for organic deposits were determined directly from this map for each section.

For clayey deposits, a severity scale, based upon a relationship between the soil texture and the Unified Soil Classification System, was combined with the frequency of occurrence rating of clayey deposits obtained from the national soils map.

The poor support potential was rated at five levels: (VW) very widespread, (M-W) medium to widespread, (L-M) limited to medium, (N-L) non-existent to limited, and (NE) non-existent.

The study indicated the limited regional distribution of organic terrain in the Adjacent 48 States. This distribution is concentrated in youthful (geomorphic) glacial and coastal terrain due to the rather poorly integrated



drainage system often associated with these regional geomorphic areas.

Although clayey deposits occur throughout the Adjacent 48 States, the greater concentration of them is east of the Rocky Mountains. The climatic, topographic and parent material factors are generally more favorable in the latter areas for the development of clay minerals.



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INTRODUCTION

While engineering design and construction decisions are unique solutions to particular problems, they may depend strongly upon the store of highly relevant experiences which the engineers use as background or perspective input. The requisite input for highway design and construction decisions is developed through a process of convergence, for example, moving from a general understanding of a large piece of geography to the specifics of a site or route which is no more than a point or a thin line on any but a very large scale map.

The search for geographic units within which ground conditions, other environmental factors, engineering problems, and presumably, design and construction practice, demonstrate significant homogeneity, has led a number of engineers to study the work of physiographers and regional geomorphologists. These scientists classify and map areas based upon their mode of topographic expression, which in turn depends principally upon the factors of structure, process and stage. Since these factors can be practically interpreted as parent material, origin, and age, (19)¹ it is not surprising that the physiographic mapping is useful. The mapped units of interest to engineers are, from largest to smallest, the province, section and subsection.

1. Underlined numbers in parentheses refer to entries in the List of References.



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PURPOSE

The objective of this paper is to report an investigation of the distribution of soils which afford potentially poor support for highway structures, and the correlation of this distribution to an extant system for the Adjacent 48 States. Two general soil categories were identified as providing "poor" support: organics and clays. The organics are extremely poor as foundations for embankments or other structures and are of course unacceptable as subgrade or embankment¹ materials. The clays are potentially troublesome as foundations or in compacted layers, due primarily to their low permeability and their sensitivity to changes in water content, viz., changes in strength and volume.

The classification selected was a slightly modified version of the Woods-Lovell Engineering-Physiographic System, presented in 1960 (17), which has 97 "unique" areas². Table 1 lists each section and provides a code for its location shown in Figure 1.

METHOD OF ANALYSIS

General

The qualitative evaluation of potentially poor soil support areas within each section was based primarily upon a national soil texture map, developed

1. Placement in certain non-critical portions of the embankment, excepted.

2. Termed Physiographic Sections.

Table 1
Physiographic Unit Code

1. Western Mountains of the Pacific Coast Range Province
 - a. Olympic Mountain Section
 - b. Oregon Coast Range Section
 - c. Klamath Mountain Section
 - d. California Coast Range Section
 - e. Los Angeles Range Section
2. Sierra - Cascade Province
 - a. Northern Cascade Mountain Section
 - b. Southern Cascade Mountain Section
 - c. Sierra Nevada Section
 - d. Lower California Section
3. Pacific Troughs Province
 - a. Puget Sound Section
 - b. Willamette Valley Section
 - c. California Valley Section
4. Columbia Plateau Province
 - a. Walla-Walla Section
 - b. Blue Mountain Section
 - c. Snake River Plains Section
 - d. Payette Section
 - e. Harney Section
5. Basin and Range Province
 - a. Great (Closed) Basin Section
 - b. Sonoran Desert Section
 - c. Salton Trough Section
 - d. Open Basin (Mexican Highland) Section
 - e. Sacramento Highland Section
 - f. Great Bend Highland Section
6. Colorado Plateau Province
 - a. High Plateaus of Utah Section
 - b. Uinta Basin Section
 - c. Canyon Lands Section
 - d. Navajo Section
 - e. Grand Canyon Section
 - f. Dettl Section
7. Northern Rocky Mountain Province
 - a. Montana Section
 - b. Bitterroot Section
 - c. Salmon River Section
8. Middle Rocky Mountain Province
 - a. Yellowstone Section
 - b. Bighorn Mountain Section
 - c. Wind River Mountain Section
 - d. Wasatch Section
 - e. Uinta Mountain Section
9. Southern Rocky Mountain Province
 - a. Front Range
 - b. Western Section
 - c. San Juan Mountain Section
10. Great Plains Province
 - a. Glaciated Missouri Plateau Section
 - b. Unglaciated Missouri Plateau Section
 - c. Bighorn Basin Section
 - d. Wyoming Basin Section
 - e. Black Hills Section
 - f. High Plains Section
 - g. Colorado Piedmont Section
 - h. Raton Upland Section
 - i. Pecos Valley Section
 - j. Plains Border Section
 - k. Central Texas Mineral Section
 - l. Edwards Plateau Section
 - m. Osage Plains Section
11. Central and Eastern Lowlands Province
 - a. St. Lawrence Lowland Section
 - b. Champlain Lowland Section
 - c. Hudson River Valley Section
 - d. Mohawk River Valley Section
 - e. Eastern Lakes and Lacustrine Section
 - f. Central Till Plain Section
 - g. Driftless Section
 - h. Western Lakes and Lacustrine Section
 - i. Dissected Loessial and Till Plain Section
12. Laurentian Upland Province
 - a. Superior Upland Section
 - b. Adirondack Section
13. Ozark and Ouachita Province
 - a. St. Francois Mountain Section
 - b. Springfield-Salem Plateau Section
 - c. 1. Boston Mountain Section
 2. Arkansas Valley Section
 3. Ouachita Mountain Section
14. Interior Low Plateaus Province
 - a. Blue Grass Section
 - b. Nashville Basin Section
 - c. Shawnee Hills Section
 - d. Highland Rim Section
15. Appalachian Plateau Province
 - a. Catskill Mountain Section
 - b. New York Glaciated Section
 - c. Allegheny Mountain Section
 - d. Kanawha Section
 - e. Cumberland Section
16. Newer Appalachian (Ridge and Valley) Province
 - a. Pennsylvania-Maryland-Virginia Section
 - b. Tennessee Section
17. Older Appalachian Province
 - a. Blue Ridge Section
 - b. Piedmont Section
18. Triassic Lowland Province
19. New England Maritime Province
 - a. Seaboard Lowland Section
 - b. New England Upland Section
 - c. Connecticut Lowland Section
 - d. White Mountain Section
 - e. Green Mountain Section
 - f. Taconic Section
 - g. Reading Prong Section
20. Atlantic and Gulf Coastal Plain Province
 - a. Embayed Section
 - b. Sea Island Section
 - c. Florida Section
 - d. East Gulf Section
 - e. Mississippi Loessial Upland Section
 - f. Mississippi Alluvial Plain Section
 - g. West Gulf Section

Note: Numbers Represent Physiographic Provinces
Letters Represent Physiographic Sections

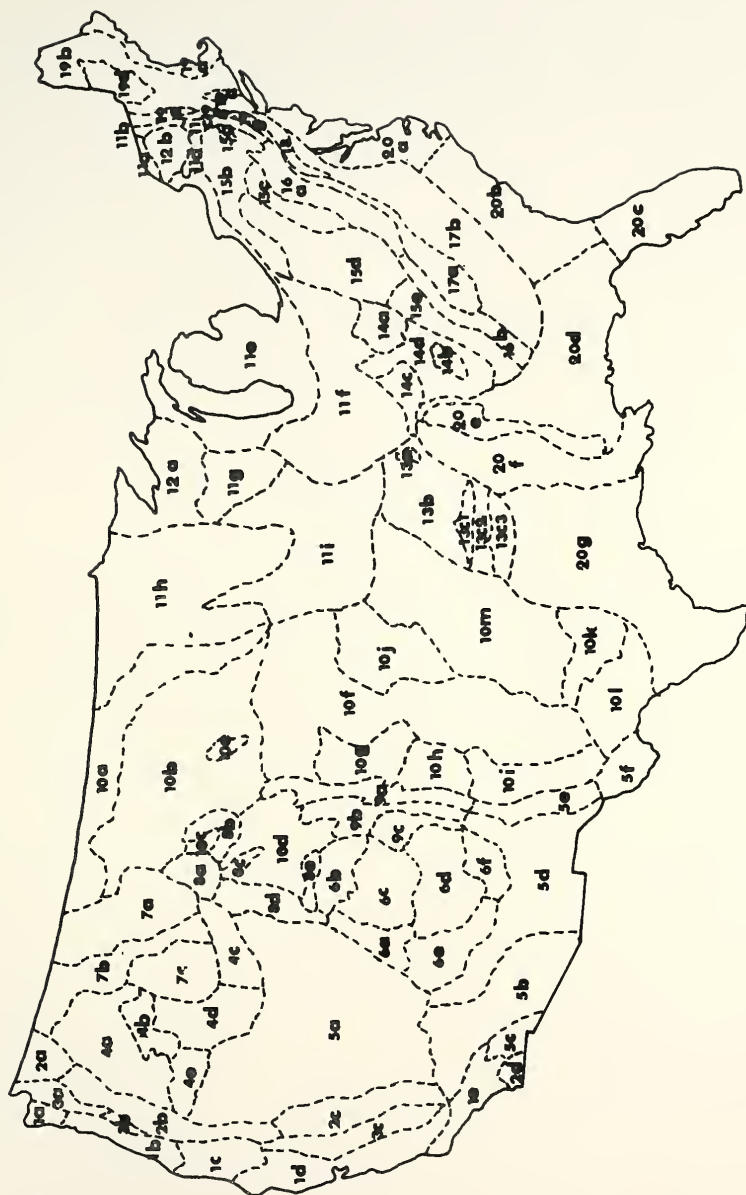


FIG 1 PHYSIOGRAPHIC DIAGRAM OF THE U.S.



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by the senior author, and used in conjunction with the map of physiographic sections. For the clayey soils, a combined severity-frequency rating was devised, while for the organics, ratings were based upon the relative frequency of occurrence.

The following portions of this paper briefly describe the methods used: (1) to develop the soils texture map, and (2) to obtain an estimate of the magnitude of the poor soil support problem within each of the 97 sections comprising the Adjacent 48 States.

Soil Texture Map

The generalized soil textural map of the United States was developed to a scale of 1:2,500,000, which corresponds to the scale of the national geologic map (11) as well as the pedologic map (4).

Many references were consulted in the preparation of the map. Principal among these were reports and mappings of soil distribution for national, regional or state coverage.

Within the national group were references (5, 6, 9, 13, 17, 18). Regional Soil references were available for the western United States (16), north central region (12), southeast region (14) and the northeastern United States (10). Many individual state soil maps were heavily consulted for soil data. The references varied widely in content and in date of preparation, e.g., only old coverage was available for some geographic areas (7, 8), while very modern information was located for others (3, 15).

The mapping technique was designed to retain as much detailed soil

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information as practicable. This amounted to preserving rather adequate descriptions of soil texture. The information available varied from classification by engineering systems to such generalities as "fine textured" or "moderately coarse." Table 2, developed from references (1) and (2), was helpful in the requisite interpretations and correlations of descriptions.

Every attempt was made to distinguish and map the general texture of the parent material. Within residual soil areas, this was not always possible and major emphasis was placed on the general texture in the subsoil as well as the weathered parent materials.

Organic Deposits

The term "organic deposits" refers to peat bogs, muck lands, and associated swamps and tidal marshes. The relative frequency of occurrence of these deposits within each physiographic unit was evaluated directly from the national soils texture map. An arbitrary rating code was devised as follows: (VW) very widespread, (M-W) medium to widespread, (L-M) limited to medium, (N-L) non-existent to limited and (NE) non-existent.

Clayey Deposits

Foundation and subgrade problems with inorganic soils are not confined to clays, but a number of difficulties are correlated with clayeyness. Accordingly, the rating of sections was accomplished by a combined consideration of the clayeyness of the soils and the frequency of occurrence of such soils.

The two coarse categories of Table 2, i.e., coarse and moderately coarse,

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 J. STURGEON, at the
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Table 2
General Soil Classification Correlation

<u>General Texture</u>	<u>Texture Type</u>	<u>U.S.C.S.¹ Most Probable</u>	<u>U.S.C.S. Other</u>
Coarse	Gravel	GP; GW	GM; GC
	Sand	SM; SP- SM	SM- SC
	Loamy Sand	SM	SC
Moderately Coarse	Sandy Loam	SM	ML; SC
	Fine Sandy Loam	SM; ML	SC; SM
Medium	Very Fine Sandy Loam	SM; ML	ML; ML-CL ML; ML-CL
	Loam	CL	
	Silt Loam	CL	
Moderately Fine	Sandy Clay Loam	CL	SC
	Silt	ML	CL
	Silty Clay Loam	CL	CH
	Clay Loam	CL	CH
Fine	Sandy Clay	SC; CL	CL
	Silty Clay	CH	CL; MH
	Clay	CH	

Note: Developed from references (1, 2).

1. Unified Soil Classification System



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are considered to afford satisfactory support. The finer textures were grouped into four severity categories, based upon the most probable Unified Soil Classification, also given in Table 2, which are shown in Table 3.

Severity ratings were then qualitatively formulated for each section by combining distributive information with the general severity categories of Table 3. The arbitrary rating code used the same five descriptors as was used for the organic deposits.

RESULTS

Soil Texture Map

The soil texture map of the United States is shown in six sheets (Figures 2 to 7). In general, three broad categories of units are mapped. They are: (a) single-textured units, (b) multiple-textured units and (c) gradationally-textured units. When soil types occur in combination, and one is known to dominate, it is underlined in the designations. The legend for the soil types is shown in Figure 2 and is considered to be self-explanatory.

Organic Deposits

Table 4 summarizes the frequency of occurrence rating of organic deposits by sections. Figure 8 illustrates the distribution of the summary table. In addition, the soil texture maps (Figures 2 to 7), illustrate the actual regional distribution of these deposits.

Table 3

Generalized Severity Category of Poor
Support Potential by Textural Classification

<u>Category</u>	<u>Textural Classification</u>	<u>Most Probable U.S.C.S. Category</u>	<u>Other U.S.C.S. Categories</u>
1 (Least Severe)	Sandy Clay Sandy Clay Loam	SC; CL CL	SC
2	Silt Silt Loam Loam	ML CL CL	CL ML; ML-CL ML; ML-CL
3	Clay Loam Silty Clay Loam	CL CL	CH CH
4 (Most Severe)	Silty Clay Clay	CH CH	CL CL

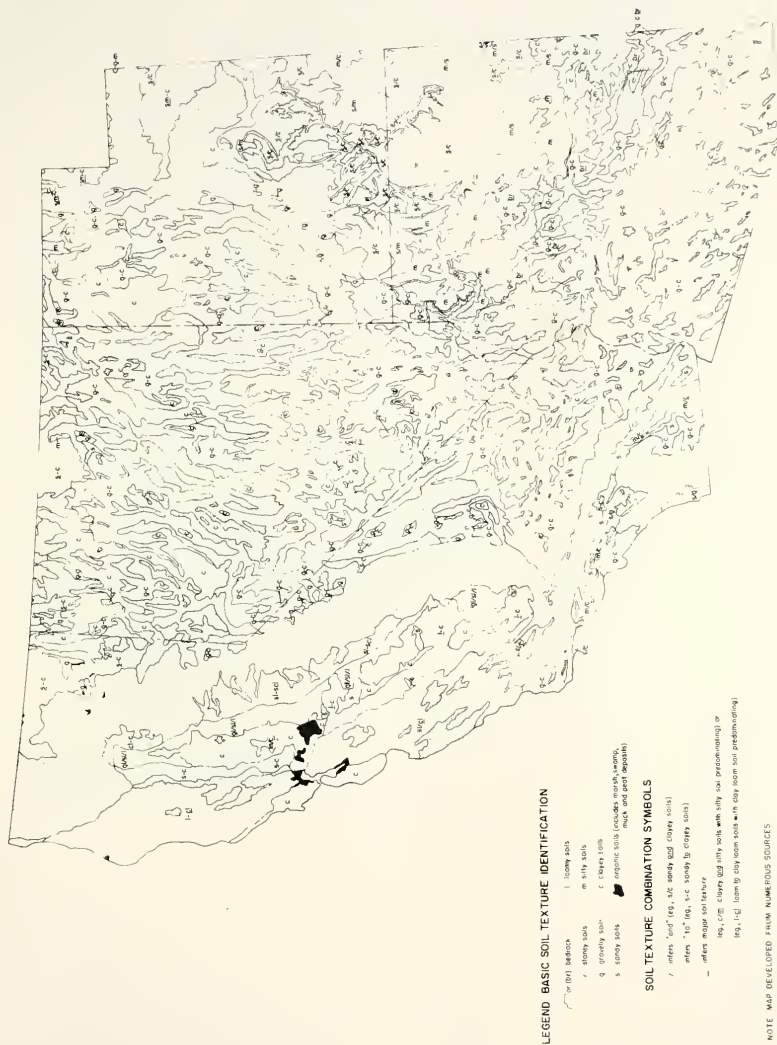


FIGURE 2
GENERALIZED SOIL TEXTURE MAP OF THE CONTINENTAL
UNITED STATES (MAP SHEET I: SOUTHWEST U.S.)

FIGURE 3
GENERALIZED SOIL TEXTURE MAP OF THE CONTINENTAL
UNITED STATES (MAP SHEET II: NORTHWEST U.S.)

FIGURE 3

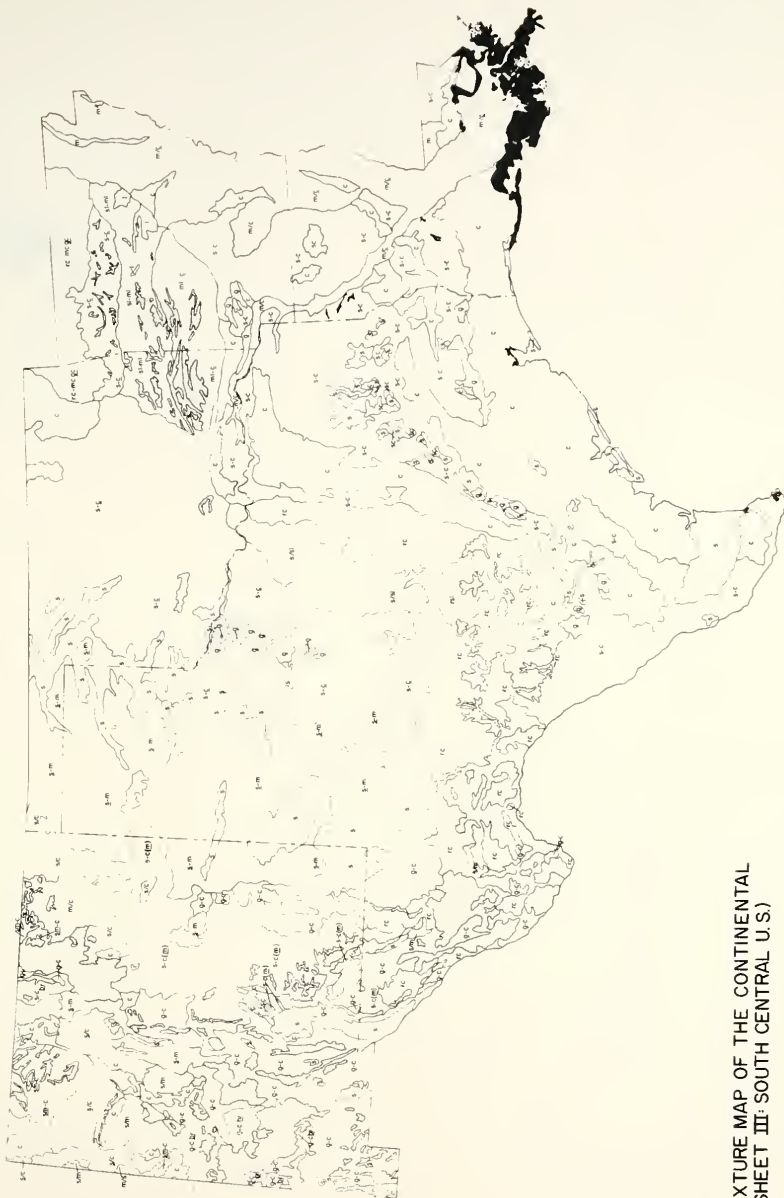


FIGURE 4
GENERALIZED SOIL TEXTURE MAP OF THE CONTINENTAL
UNITED STATES (MAP SHEET III: SOUTH CENTRAL U.S.)

NOTE SEE MAP SHEET 1 FOR LEGEND



NOTE SEE MAP SHEET I FOR LEGEND

FIGURE 6
GENERALIZED SOIL TEXTURE MAP OF THE CONTINENTAL
UNITED STATES (MAP SHEET V: SOUTHEAST U.S.)



FIGURE 7
GENERALIZED SOIL TEXTURE MAP OF THE CONTINENTAL
UNITED STATES (MAP SHEET VI-NORTHEAST U.S.)

Table 4
Summary of Estimated Frequency of Occurrence Rating
of Organic Areas Within Sections

Section Code	Non Existent		Non Existent to Limited		Limited to Medium		Medium to Widespread		Very Widespread	
	Section Code	Area	Section Code	Area	Section Code	Area	Section Code	Area	Section Code	Area
1c,e		41,830	1a,b,d	60,930	--	--	--	--	--	--
2a,b,c,d		90,670	--	--	--	--	--	--	--	--
3b		4,700	3a,c	37,610	--	--	--	--	--	--
4a,b,c,d		99,000	4e	15,850	--	--	--	--	--	--
5a,b,c,d,e		362,690	--	--	--	--	--	--	--	--
6a,b,c,d,e,f		123,920	--	--	--	--	--	--	--	--
7a,b,c		105,780	--	--	--	--	--	--	--	--
8a,b,c,e		28,200	8d	17,140	--	--	--	--	--	--
9a,b,c		60,450	--	--	--	--	--	--	--	--
10a-m		652,840	--	--	--	--	--	--	--	--
11i		89,580	11b,c,d,f,g	114,730	11a,h	100,590	11e	88,010	--	--
--		--	--	--	12a,b	72,540	--	--	--	--
13a,b,c1,c2,c3		66,490	--	--	--	--	--	--	--	--
14a,b,c,d		51,380	--	--	--	--	--	--	--	--
15a,c,d,e		80,260	15b	22,500	--	--	--	--	--	--
16a,b		45,340	--	--	--	--	--	--	--	--
17a,b		90,670	--	--	--	--	--	--	--	--
--		--	18	6,040	--	--	--	--	--	--
19e,f,g		8,760	19b,c,d	48,940	19a	11,820	--	--	--	--
20e		22,860	20d,f,g	278,420	20a,b	87,180	20c	34,680	--	--
Total		2,025,420		602,160		272,130		122,690	0	0
Percent of)										
Adjacent :		67.0		19.9		9.0		4.1		
48 States)										

Note: 1. Areas given in square miles

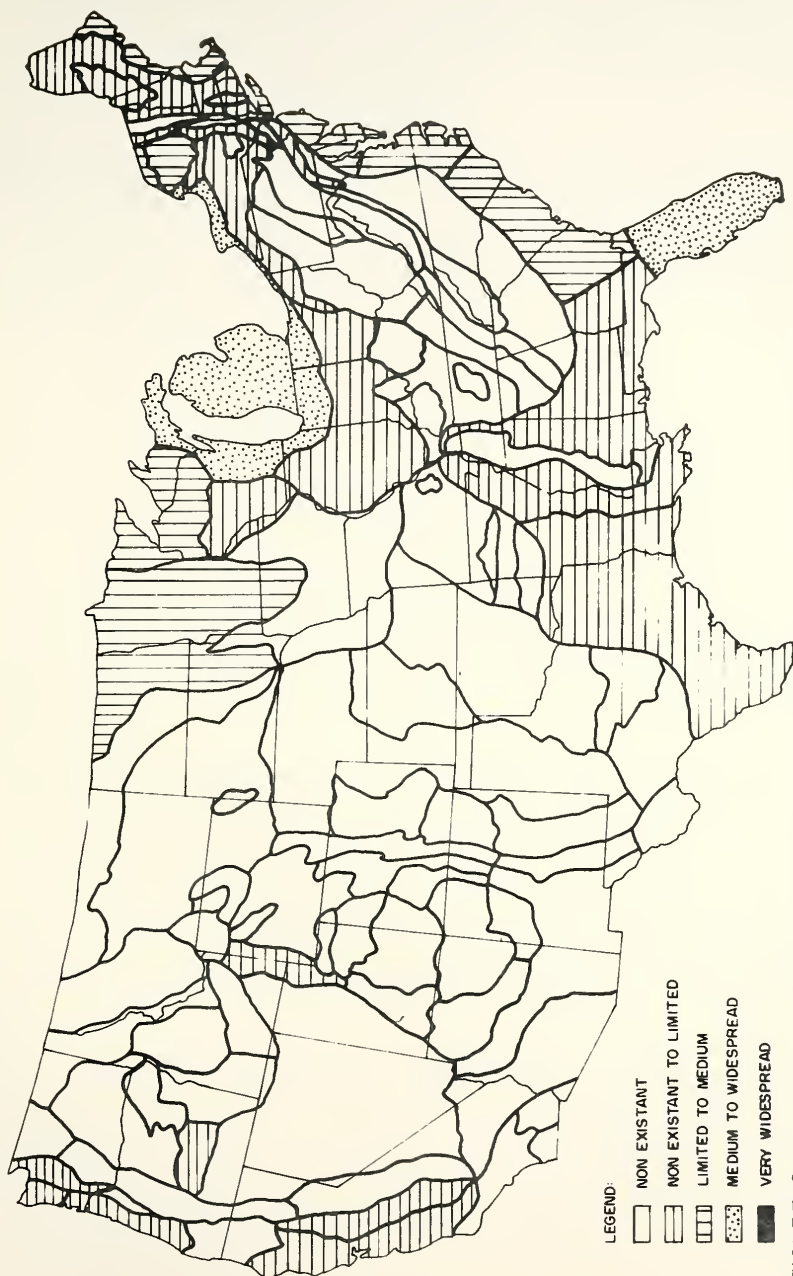


FIGURE 8
ESTIMATED FREQUENCY OF OCCURRENCE RATING OF POTENTIAL POOR SUBGRADE SUPPORT
AREAS (ORGANIC DEPOSITS) BY PHYSIOGRAPHIC UNIT

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Clayey Deposits

Table 5 summarizes the estimated frequency of occurrence-severity rating of clayey soils within each section, while Figure 9 illustrates the geographic distribution of the ratings. The actual regional distribution may be deduced from Figure 2 to 7.

SUMMARY AND CONCLUSIONS

Organic Deposits

The occurrence of organic deposits is relatively limited in the U.S.. As can be noted from Table 8, physiographic sections comprising an area of almost 87% of the Adjacent 48 States have, at most, a "non-existent to limited" rating.

The greatest frequency ratings occur for the Eastern Lakes and Lacustrine Plains Section of the Central and Eastern Lowland Province, and the Florida Section of the Atlantic and Gulf Coastal Plain Province. It is within these two geomorphic conditions, viz., glaciation and coastal plain development, that organic type terrain becomes a significant factor in highway engineering.

Table 6 summarizes the sections possessing organic deposits, grouped by the major geomorphic modes of occurrence. A salient geomorphic condition for organics is associated with youthfulness on transported deposits. This is due in part to the fact that youthful terrains are often associated with poorly integrated drainage systems.

Table 5
Summary of Estimated Frequency of Occurrence-Severity
Rating of Clayey Soil Areas Within Sections

Non Existent		Non Existent to Limited		Limited to Medium		Medium to Widespread		Very Widespread	
Section Code	Area ¹	Section Code	Area	Section Code	Area	Section Code	Area	Section Code	Area
1c	20,040	1a,b,e	44,180	1d	38,540	--	--	--	--
2a,d	22,940	2b,c	67,730	--	--	--	--	--	--
--	--	3a	14,510	3b	4,700	3c	23,100	--	--
4a,b,c,e	94,290	4d	20,560	--	--	--	--	--	--
--	--	5b,d,e,f	176,630	5a	175,540	5c	10,520	--	--
--	--	6a,b,c,d,e	114,630	6f	9,290	--	--	--	--
7b,c	61,980	7a	43,800	--	--	--	--	--	--
8a,b,c,e	28,200	8d	17,140	--	--	--	--	--	--
9a,b,c	60,450	--	--	--	--	--	--	--	--
--	--	10c,d,e,f,i,j,k	268,310	10a,g,h,l	150,160	10b,m	234,370	--	--
--	--	11g,h	119,060	11d,e	90,370	11a,b,c,f,i	183,480	--	--
12b	8,990	12a	63,550	--	--	--	--	--	--
--	--	13a,c2	12,300	13b,c1,c3	54,190	--	--	--	--
--	--	--	--	14c	16,540	14d	23,580	14a,b	11,260
--	--	15a,e	23,640	15b,c	33,190	15d	45,930	--	--
--	--	--	--	16a,b	45,340	--	--	--	--
17a	19,770	--	--	--	--	17b	70,900	--	--
--	--	--	--	--	--	18	6,040	--	--
19c,d,e,g	20,160	19b,f	37,540	--	--	19a	11,820	--	--
--	--	20a,b,e	110,040	20c,d	126,920	20g	140,480	20f	45,700
Total	336,820		1,133,620		744,780		750,220		56,960
Percent of)									
Adjacent :	11.2		37.6		24.5		24.8		1.9
48 States)									

Note: 1. Areas given in square miles

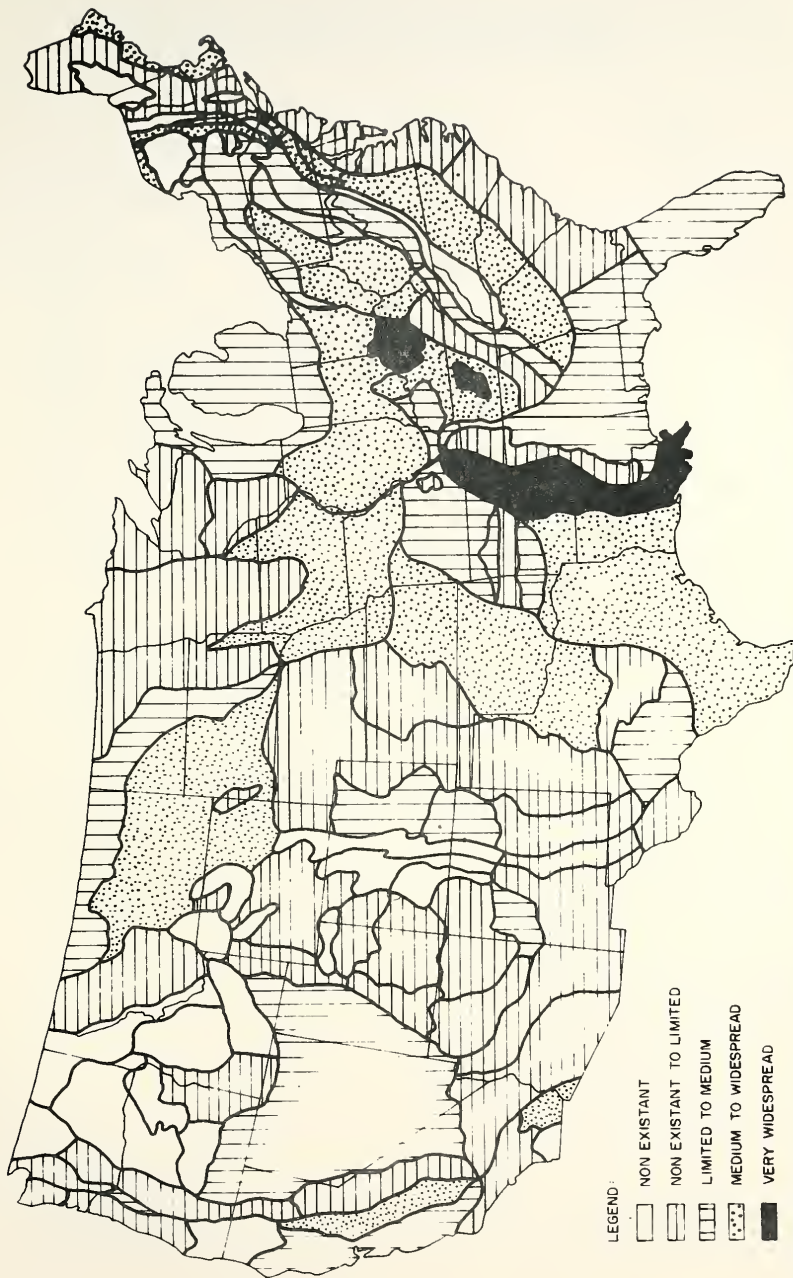


FIGURE 9
ESTIMATED FREQUENCY-SEVERITY OCCURRENCE RATING OF POTENTIAL POOR SUBGRADE SUPPORT
AREAS (INORGANIC/CLAYEY DEPOSITS) BY PHYSIOGRAPHIC UNIT

Table 6

Summary of Sections Possessing Organic
Deposits Grouped by Major Geomorphic Modes

<u>Section/Code</u>	<u>Rating</u>	<u>Remarks</u>
I. Glaciated Areas		
Puget Trough (3a)	N-L	
Wasatch (8d)	N-L	found with glacial outwash in Jackson Hole area
Champlain Lowland (11b)	N-L	
Hudson River Valley (11c)	N-L	
Mohawk River Valley (11d)	N-L	
Central Till Plain (11f)	N-L	
St. Lawrence Lowland (11a)	L-M	
Western Lakes and Lac. (11h)	L-M	
Eastern Lakes and Lac. (11e)	M-W	
Superior Upland (12a)	L-M	
Adirondack (12b)	L-M	
New York Glaciated (15b)	N-L	
Triassic Lowland (18)	N-L	associated with northern glaciated area
New England Upland (19b)	N-L	
Connecticut Lowland (19c)	N-L	
White Mountain (19d)	N-L	
Seaboard Lowland (19a)		
II. Coastal and Embayed Areas		
Oregon Coast Ranges (1b)	N-L	found within small coastal plain areas of Oregon
California Coast Ranges (1d)	N-L	associated with Section (3c) within San Francisco Bay area
California Valley (3c)	N-L	associated with Section (1d) within San Francisco Bay area
East Gulf Coast (20d)	N-L	occurs primarily in outer coastal plain
West Gulf Coast (20g)	N-L	occurs primarily in outer coastal plain
Embayed (20a)	L-M	
Sea Island (20b)	L-M	
Florida (20c)	M-W	possesses largest swamp area in United States
III. Deltaic Areas		
Mississippi Alluvial Plain (20f)	N-L	associated with Mississippi delta area

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Clayey Deposits

Table 5 indicates that over 26% of the Adjacent 48 States has a frequency of occurrence-severity rating of clayey soils more severe than "limited-to-medium. " Perhaps even more significant is the obvious concentration of clayey areas in the eastern province grouping.¹ Approximately 75% of the western province grouping area possesses sections having a rating of less than or equal to a "non-existent to limited" severity rating while only slightly more than 3% of the area has sections showing a "medium to widespread" or greater rating. In contrast, the eastern group has almost 40% of its area having sections with a "medium to widespread" or greater rating.

There are several probable reasons for the above pattern, each perhaps interrelated to the others. It is felt that the major factors are due to the following:

1. The climatic environment (humid type) prevalent in the east is more conducive to chemical weathering processes which generally are associated with clay development in contrast to physical weathering.
2. The overall topographic features (elevation, relief) of the eastern United States are likewise more favorable for chemical weathering in combination with the climatic regime of the area.
3. The grouping of origin-parent material types in the east are conducive

1. The "western" province grouping consists of physiographic units having a code designation prefix of 1 through 9. Units comprising the "eastern" grouping are prefixed by numbers 10 through 20.

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to clay deposition and/or development. Within the glaciated northern portion of the area, the most highly plastic soils are generally associated with water deposition from glacial lacustrine or marine origin. Likewise the clays of the coastal plain are primarily found associated either with the coastal limestones and chalks or widespread fine grained alluvial deposition. Within these two zones lies the consolidated bedrock region. This area is composed primarily of sedimentary types, in which clayey type residuum is often developed within the climatic and topographic environments peculiar to this region.

While the physiographic sections used in the analysis are useful in the ratings of poor soil support. they are in general too large and variable to serve the desired purpose. Subsequently, a system of 242 subsections has been developed (19), which should permit more accurate and detailed predictions.

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